

# The Use Of Probabilistic Modeling To Determine Reentry Intervals

John H. Ross, Senior Toxicologist  
Michael H. Dong, Staff Toxicologist

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Worker Health and Safety Branch  
Department of Pesticide Regulation  
California Environmental Protection Agency  
1020 N Street, Room 200  
Sacramento, California 95814-5624

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•The opinions expressed here are those of the authors and not necessarily those of the Department or of the Agency•

## ABSTRACT

Reentry intervals are the earliest time at which workers can reenter agricultural fields safely since last pesticide application. These intervals are established by determining the time  $T$  at which the absorbed daily dosage ADD in question is expected to be less than or equal to the safe level SL. One common approach to calculating reentry interval is to determine the time at which the dislodgeable foliar residues DFR (to which workers are exposed) will be, as evident from available dissipation curves, low enough to yield the safe dosage ADD<sub>SL</sub>. Pesticide foliar dislodgeables can be converted to hourly dermal exposure equivalents through use of a transfer factor TF. The resultant exposure is then multiplied by a dermal absorption rate ABS and divided by a body weight BW to obtain the hourly dermal dosage in question. Mathematically the calculation of this reentry time  $T$  can be obtained as follows:

$$T = \frac{\{ \ln[DFR_T] - \ln[DFR_0] \}}{K} \times K^{-1}$$
$$= \frac{\{ \ln[((ADD_{SL})(BW))/((TF)(ABS)(hrs/day))] - \ln[DFR_0] \}}{K} \times K^{-1},$$

where  $K$  is the slope of the (natural) log-linear curve specified by the first-order dissipation model for DFR. Extreme single-point values are usually used for one or more of the above input exposure factors. This conservative approach has a major drawback in that the reentry time so calculated often represents a worst-case scenario that rarely, if ever, happens. Probabilistic modeling is a more realistic alternative wherein the probability distribution of the reentry interval is calculated from the full ranges of the individual exposure factors. Using all the available foliar dislodgeable residues and the full range of transfer factors for a particular crop and work task usually reduces the estimated reentry interval at the 95th percentile considerably compared to extreme case point estimates. Probabilistic modeling requires a reasonable knowledge of the distribution of the major input variables. Relatively few pesticides have the requisite DFR (for  $DFR_0$  and  $K$ ) and TF distributions to justify using stochastic modeling. The purpose of this presentation is to compare the reentry intervals calculated from the conventional approach with those from probabilistic modeling, using worker exposures to three pesticides as case studies.

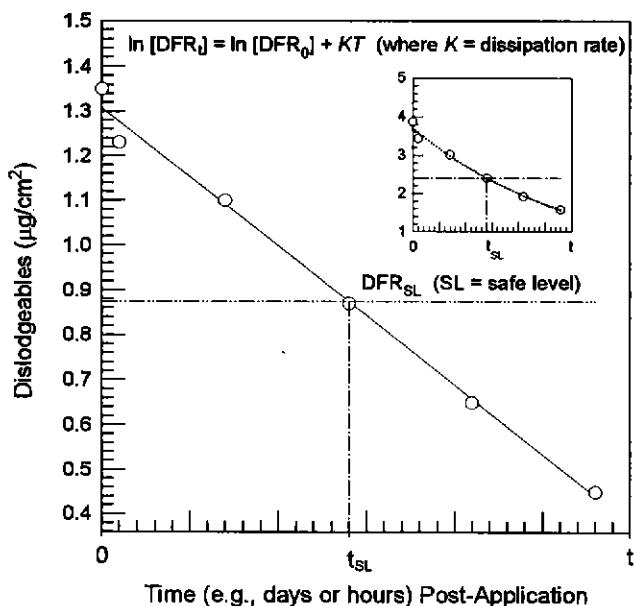
## THE PROBABILISTIC APPROACH

The simulation performed for the three case studies simply treated each (key) input exposure parameter as a random variable. It then relied on the computer to draw one value for each of these variables, and finally to compute a single reentry estimate using the values randomly selected (and, if any, also those that were fixed for nonrandom variables). This process was repeated 10,000 times to generate a representative distribution of the values simulated for the reentry in question. This set of 10,000 values was also used to provide a reasonable high-end estimator (*e.g.*, the 75<sup>th</sup> or 95<sup>th</sup> percentile) for the reentry under study. There were ten (10) trials performed to ensure both the randomness of value selection and the precision of high-end estimation.

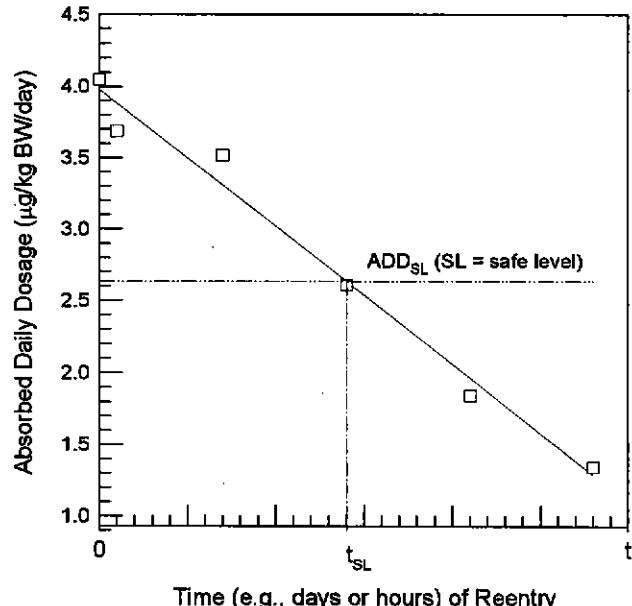
The random variables were each pre-assigned a range of values whose selection during each simulation run was governed by some pre-defined probabilistic rules. Many probabilistic rules (*i.e.*, the assumed fixed values and probability distributions) used in the simulation were based on those available in the literature. The actual simulation was implemented using the computer software *Crystal Ball* (1993).

# CALCULATION OF REENTRY TIME

**Figure 1. Typical Dissipation of Pesticide Foliar Dislodgeables (DFR) on Natural Log Scale (Those in Inset, on Linear Scale)**



**Figure 2. Typical Effect of Reentry Time on Absorbed Daily Dosage (ADD) Received by Workers**



**ADD** ≡ absorbed daily dosage  
**DE<sub>h</sub>** ≡ hourly dermal exposure  
**ABS** ≡ dermal absorption  
**H/D** ≡ hours worked per day

**TF** ≡ transfer factor  
**SL** ≡ safe level  
**BW** ≡ body weight  
**DFR** ≡ dislodgeable foliar residues

- (1)  $\text{TF} = \text{DE}_h/\text{DFR}$ , or  $\text{DE}_h = \text{TF} \times \text{DFR}$
- (2)  $\text{ADD} = (\text{DE}_h \times \text{ABS} \times \text{H/D})/\text{BW} = (\text{TF} \times \text{DFR} \times \text{ABS} \times \text{H/D})/\text{BW}$
- (3)  $\text{ADD}_{\text{SL}} = [(\text{TF} \times \text{ABS} \times \text{H/D})/\text{BW}] \times \text{DFR}_{\text{SL}}$ , or
- (4)  $\text{DFR}_{\text{SL}} = (\text{ADD}_{\text{SL}} \times \text{BW})/(\text{TF} \times \text{ABS} \times \text{H/D})$
- (5)  $\ln[\text{DFR}_{\text{SL}}] = \ln[\text{DFR}_0] + K \times T$  (Fig. 1)
- (6)  $T = \{\ln[(\text{ADD}_{\text{SL}} \times \text{BW})/(\text{TF} \times \text{ABS} \times \text{H/D})] - \ln[\text{DFR}_0]\} \times K^{-1}$  (Fig. 2)

# EXPOSURE SCENARIOS

## Greenhouse Harvesters

*The following point estimate of reentry time T was calculated for an 8-hour exposure per day to a pyrethroid.*

$$\text{ADD}_{\text{SL}} = 30 \mu\text{g/kg BW/day} = \text{NOEL}/100 \text{ (on animal effects)}$$

$$\text{TF} = 700 \text{ } (\mu\text{g/h per } \mu\text{g/cm}^2 \text{ two-sided DFR, with gloves, literature data})$$

$$\text{BW} = 68.7 \text{ kg (for male/female workers since TF was based on both sexes)}$$

$$\text{ABS} = 33\% \text{ (based on a rat study for 10 hours of exposure)}$$

$$\text{DFR}_0 = 1.15 \text{ } \mu\text{g/cm}^2 \text{ (after the third application with a 3 day reapplication interval to simulate residue build-up, from a single study)}$$

$$K = -0.125 \text{ } (\mu\text{g/cm}^2 \text{ DFR per day, from the same single study})$$

$$\rightarrow T = 0.28 \text{ days (7 h)} = \{\ln[(30 \times 68.7) / (700 \times 33\% \times 8)] - \ln[1.15]\} \times -0.125^{-1}$$

*(see Equation 6 in the Reentry Calculation panel)*

## Cotton Scouts

*The following point estimate of reentry time T was calculated for a 6-hour exposure per day to methyl parathion.*

$$\text{ADD}_{\text{SL}} = 30 \mu\text{g/kg BW/day} = \text{NOEL}/10 \text{ (on human effects)}$$

$$\text{TF} = 1,000 \text{ (normal work clothes, from a single study in the literature)}$$

$$\text{BW} = 76.9 \text{ kg (for male workers since TF was based on this sex only)}$$

$$\text{ABS} = 10\% \text{ (based on a human study for 24 h of exposure to ethyl parathion)}$$

$$\text{DFR}_0 = 4.67 \text{ } \mu\text{g/cm}^2 \text{ (based on 3.0 lb AI/acre, from 9 studies in the literature)}$$

$$K = -1.12 \text{ } (\mu\text{g/cm}^2 \text{ DFR per day, from 8 studies in the literature})$$

$$\rightarrow T = 0.17 \text{ days (4 h)} = \{\ln[(30 \times 76.9) / (1,000 \times 10\% \times 6)] - \ln[4.67]\} \times -1.12^{-1}$$

## Nectarine/Peach Pickers

*The following point estimate of reentry time T was calculated for an 8-hour exposure per day to propargite.*

$$\text{ADD}_{\text{SL}} = 20 \mu\text{g/kg BW/day} = \text{NOEL}/100 \text{ (on animal effects)}$$

$$\text{TF} = 1,100 \text{ (normal work clothes, from a single study)}$$

$$\text{BW} = 76.9 \text{ kg (for male workers since TF was based on this sex only)}$$

$$\text{ABS} = 17\% \text{ (from animal studies for 10 h of exposure; Thongsinthusak, 1992)}$$

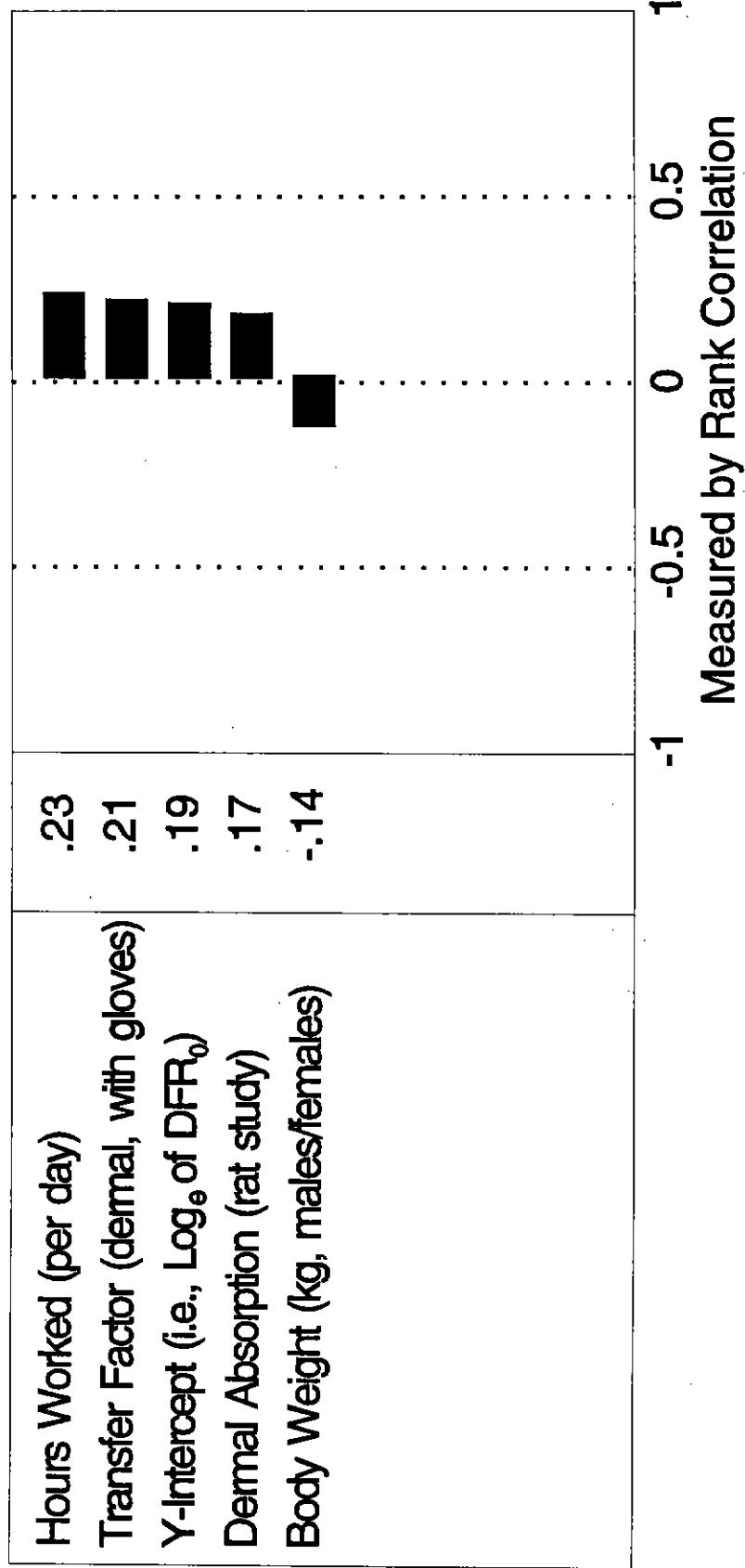
$$\text{DFR}_0 = 1.91 \text{ } \mu\text{g/cm}^2 \text{ (for 3.0 lb AI/acre, average of Y-intercepts calculated from 8 log-linear regressions of DFR)}$$

$$K = -0.039 \text{ } (\mu\text{g/cm}^2 \text{ DFR per day, from the same 8 log-linear regressions})$$

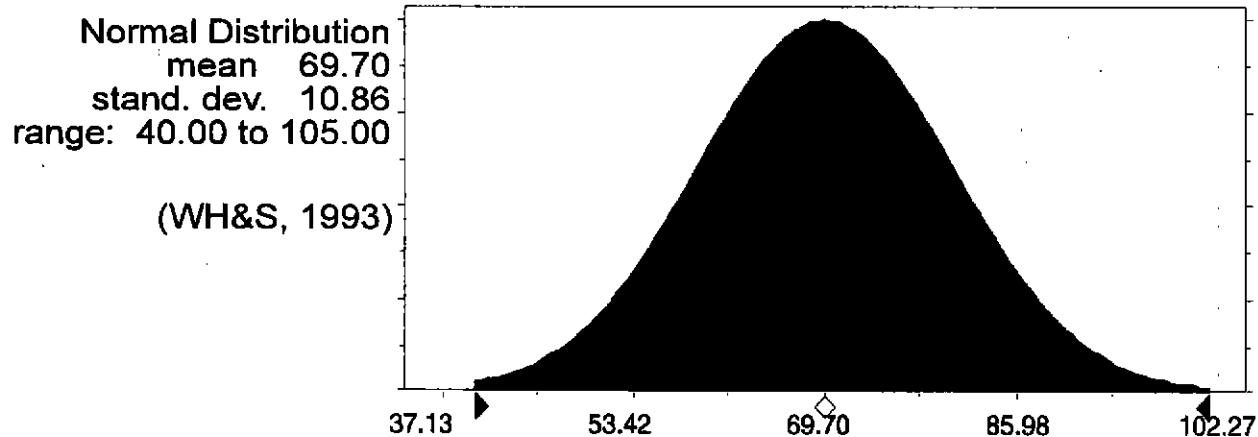
$$\rightarrow T = 15.8 \text{ days} = \{\ln[(20 \times 76.9) / (1,100 \times 17\% \times 8)] - \ln[1.91]\} \times -0.039^{-1}$$

### Sensitivity Chart

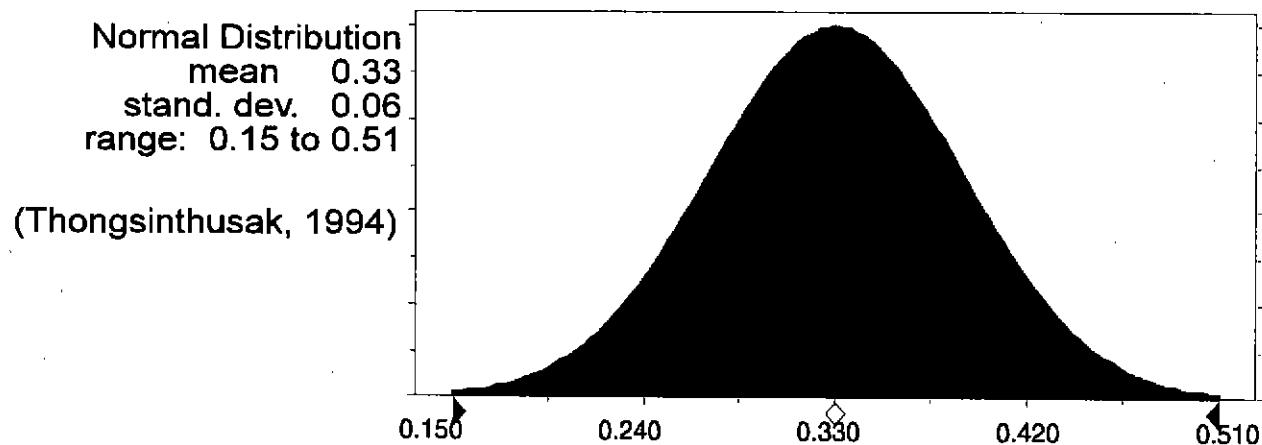
#### Target Forecast: Reentry for Greenhouse Harvesters (days)



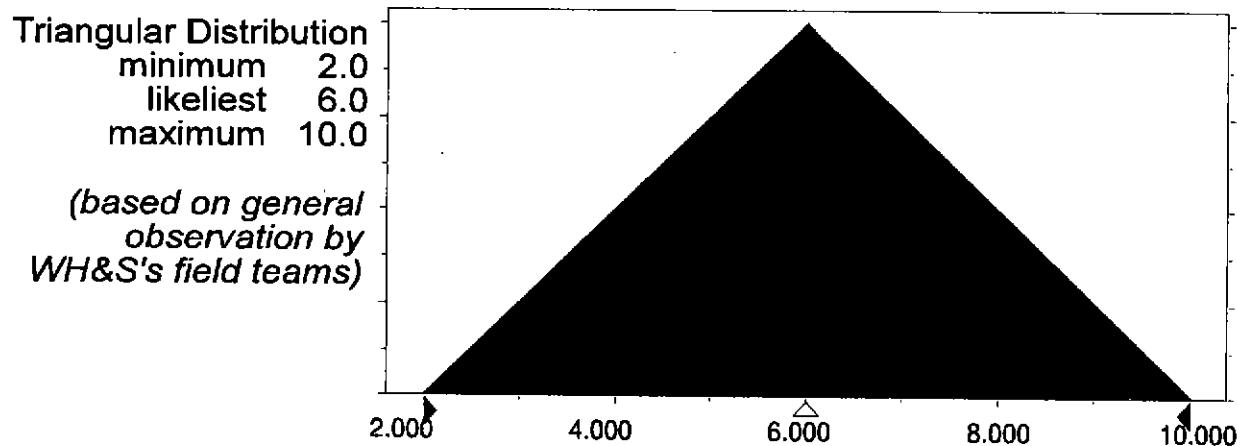
### Body Weight (kg, males/females)



### Dermal Absorption (rat study)



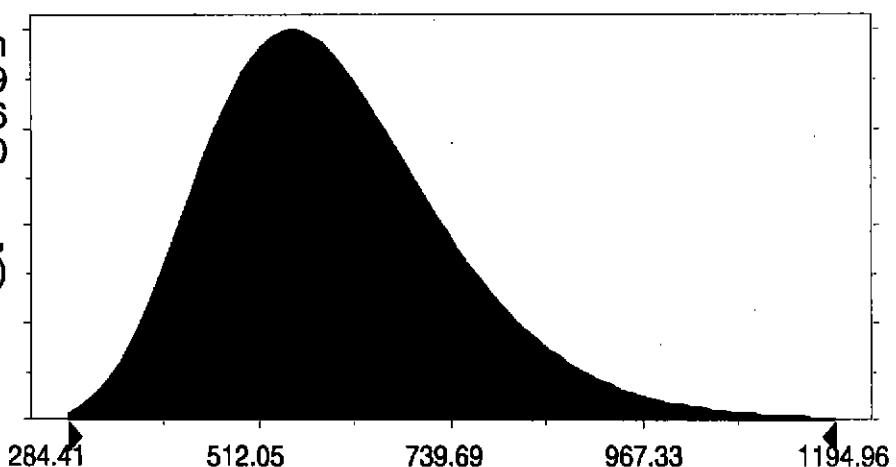
### Hours Worked (per day)



## Transfer Factor (dermal, with gloves)

Lognormal Distribution  
mean 599.9  
stand. dev. 145.6  
range: 240.0 to 1,250.0

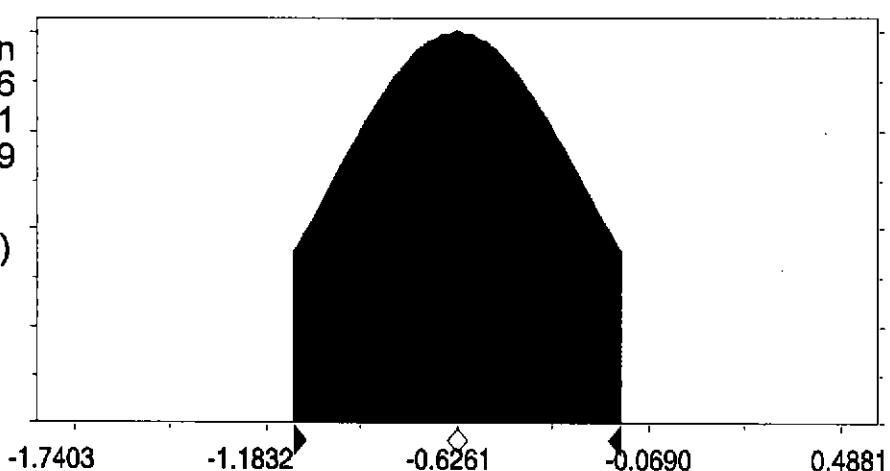
(Brouwer et al.,  
1992a, 1992b)



## Y-Intercept (i.e., Log<sub>e</sub> of DFR<sub>0</sub>)

Normal Distribution  
mean -0.626  
stand. dev. 0.371  
range: -1.103 to -0.149

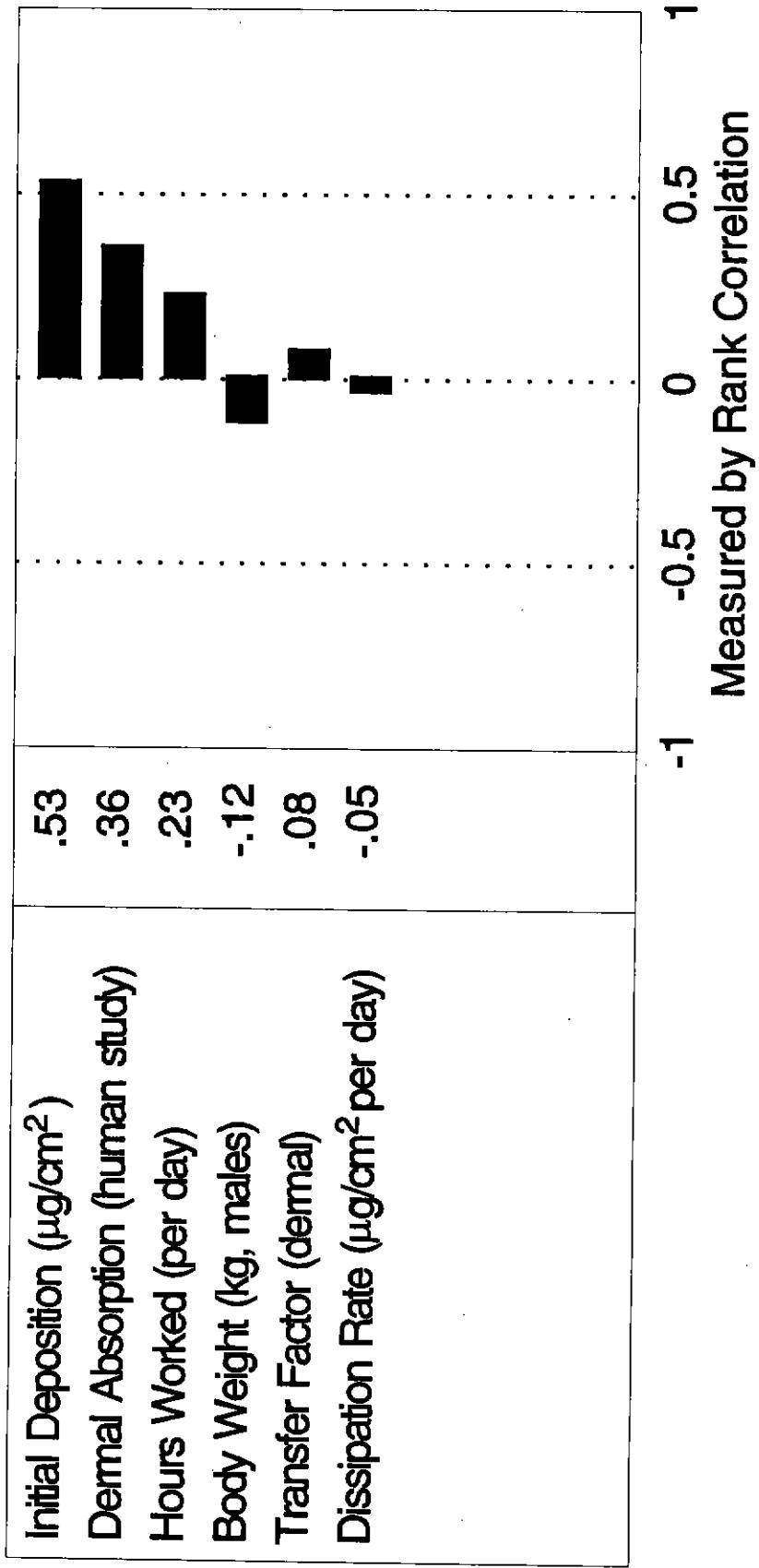
(Dong, 1994)



*Note: geometric mean is close to but not equal to the mean of a lognormal distribution; the mean used for the point estimate hence differed slightly from that used for a lognormal distribution in the simulation.*

## Sensitivity Chart

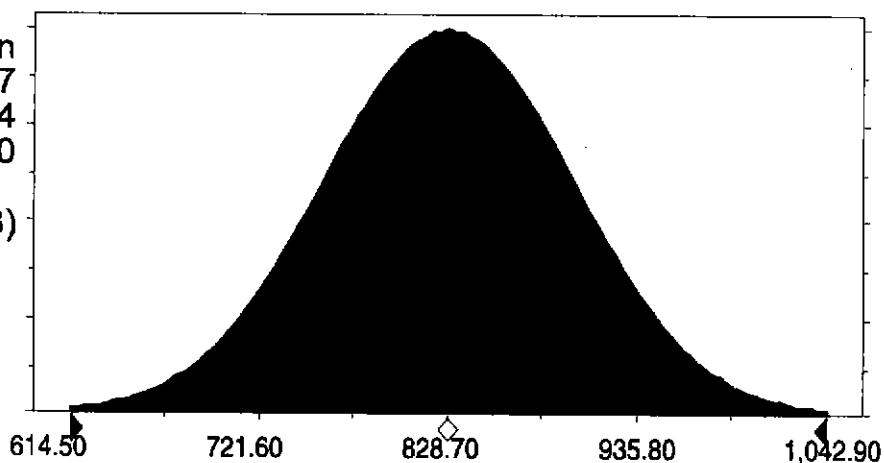
### Target Forecast: Reentry for Cotton Scouts (days)



### Transfer Factor (dermal)

Normal Distribution  
mean 828.7  
stand. dev. 71.4  
range: 600.0 to 1,050.0

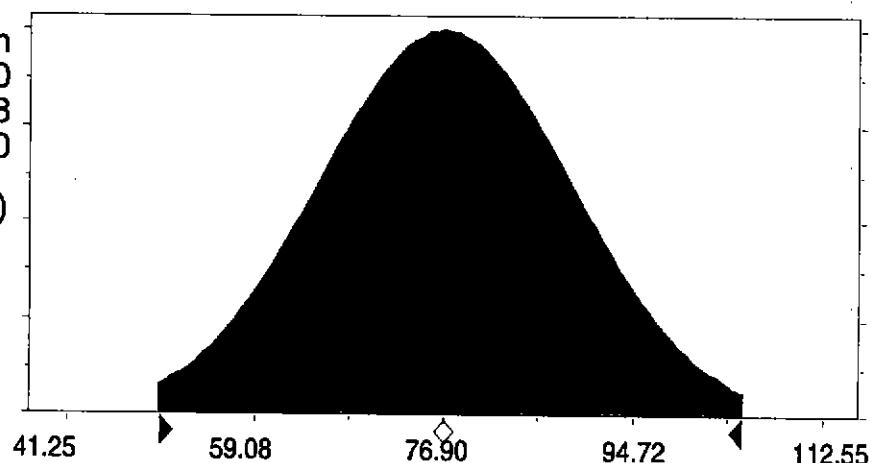
(Ware et al., 1973)



### Body Weight (kg, males)

Normal Distribution  
mean 76.90  
stand. dev. 11.88  
range: 50.00 to 105.00

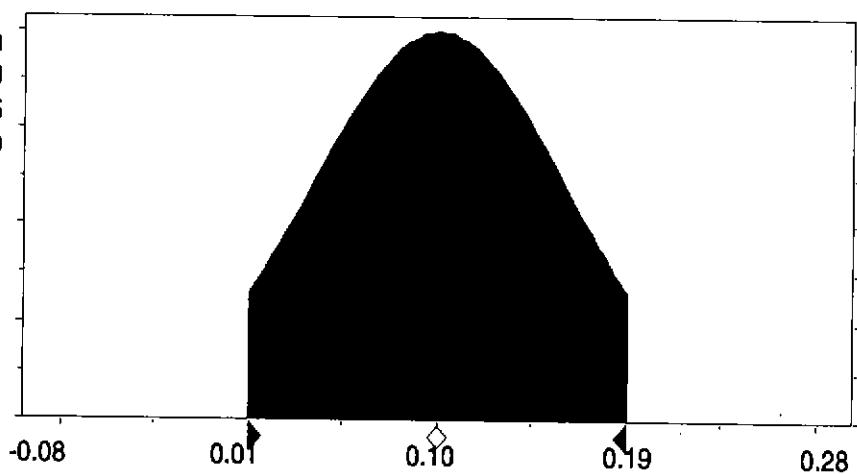
(WH&S, 1993)



### Dermal Absorption (human study)

Normal Distribution  
mean 0.10  
stand. dev. 0.06  
range: 0.01 to 0.19

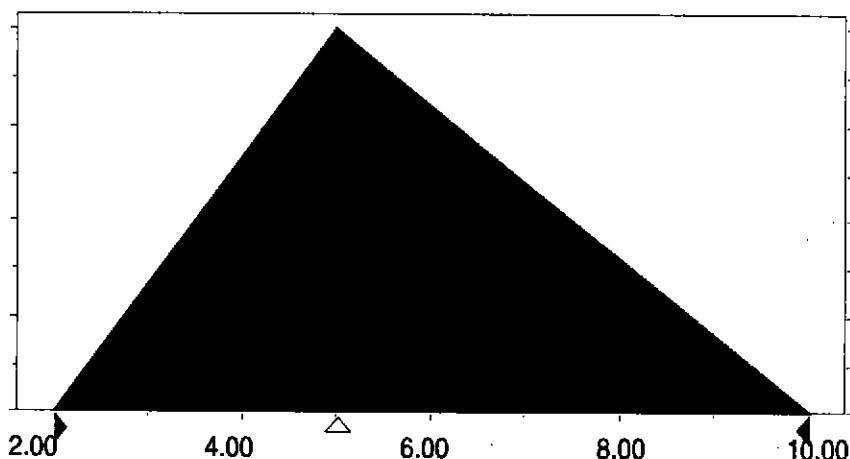
(Feldmann and  
Maibach, 1974)



### Hours Worked (per day)

Triangular Distribution  
minimum 2.0  
likeliest 5.0  
maximum 10.0

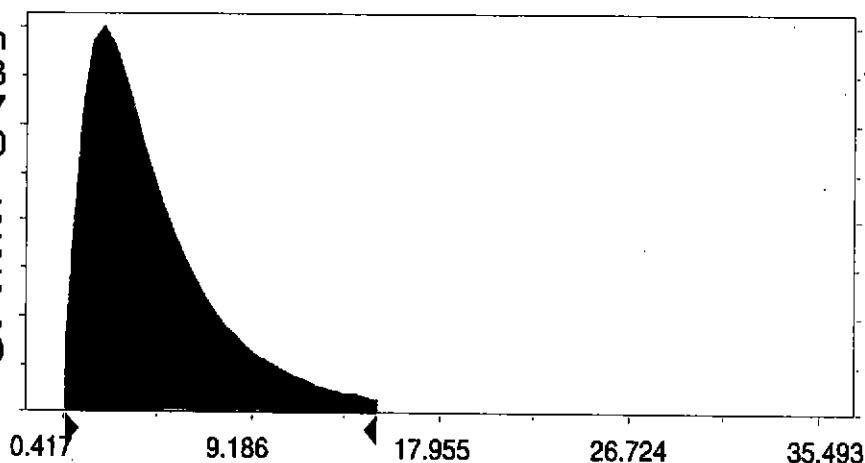
(based on general  
observation by  
WH&S's field teams)



### Initial Deposition ( $\mu\text{g}/\text{cm}^2$ )

Lognormal Distribution  
mean 5.063  
stand. dev. 4.327  
range: 0.500 to 15.000

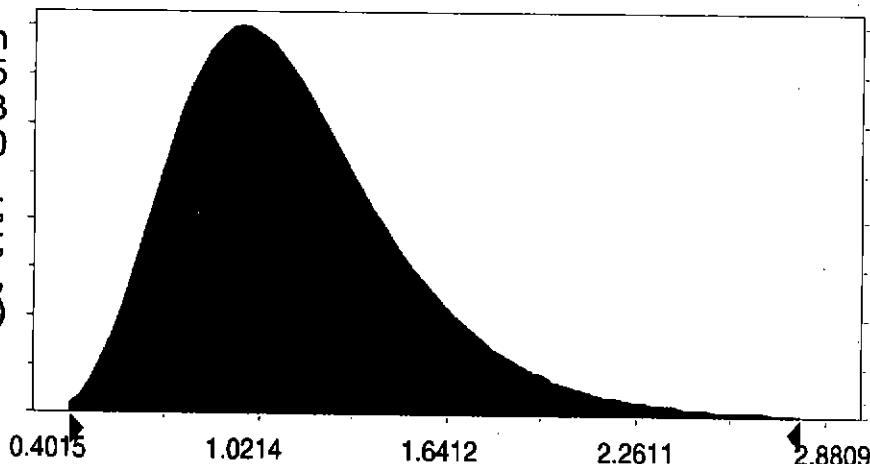
(Bigley et al., 1981;  
Buck et al., 1980;  
Cahill et al., 1975;  
Ware et al., 1973, 1974,  
1980a, 1980b, 1983)



### Dissipation Rate ( $\mu\text{g}/\text{cm}^2$ per day)

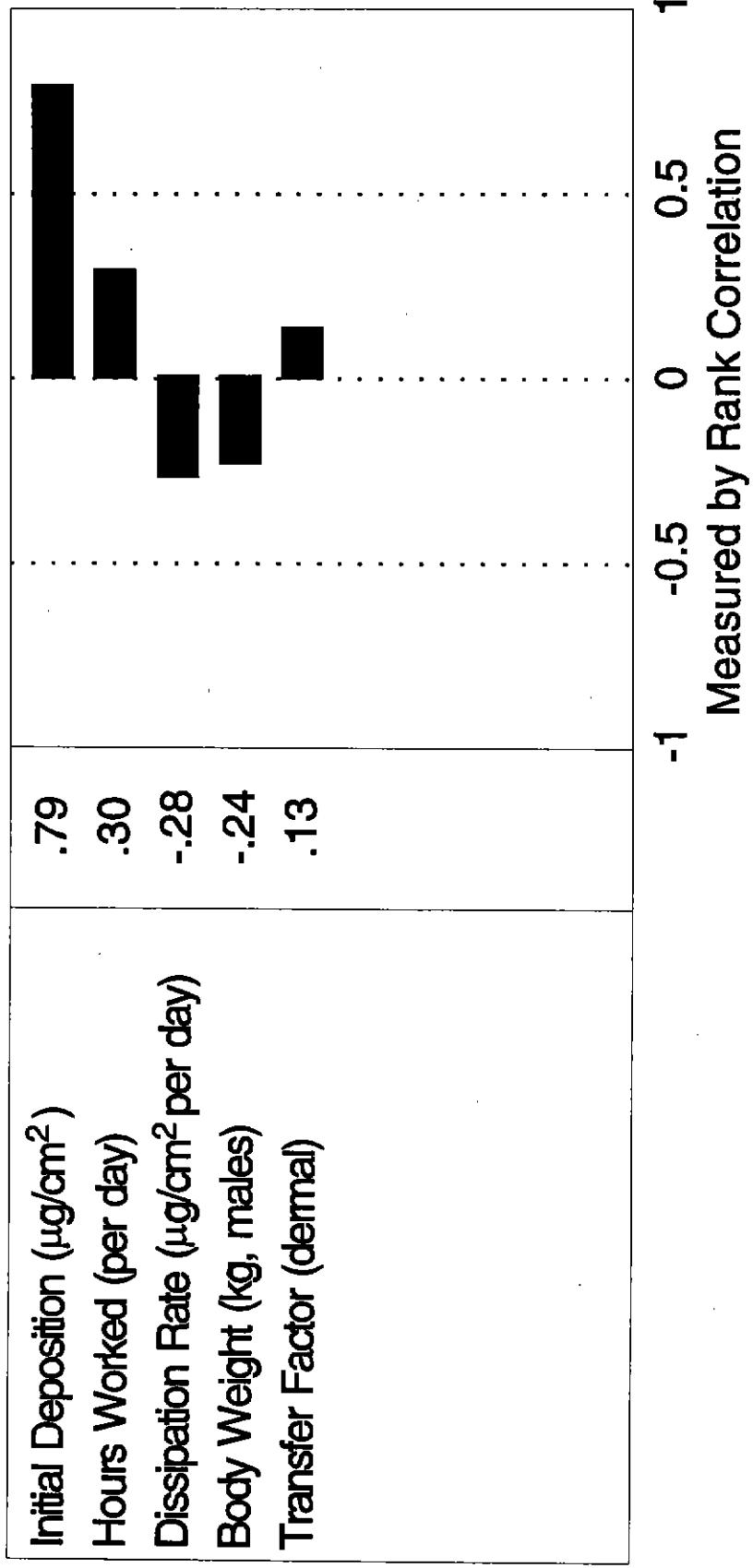
Lognormal Distribution  
mean (-) 1.135  
stand. dev. 0.383  
range: 0.300 to 2.800

(Buck et al., 1980;  
Cahill et al., 1975;  
Ware et al., 1973,  
1974, 1980a, 1983)



### Sensitivity Chart

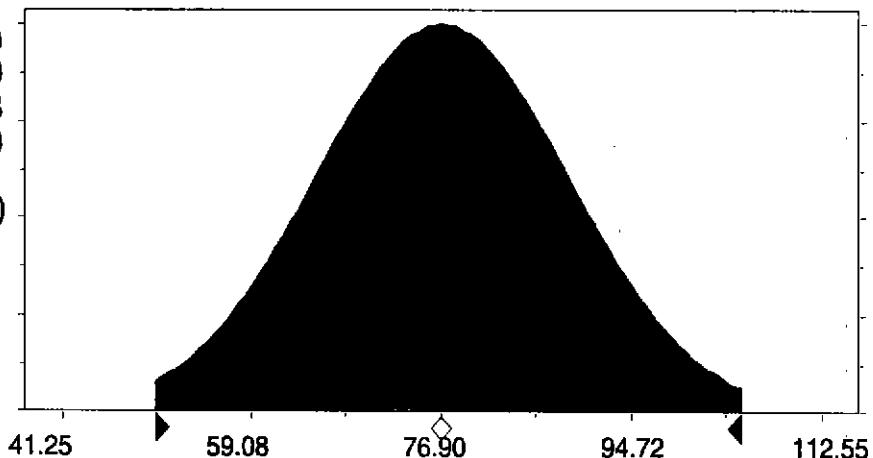
#### Target Forecast: Reentry for Nectarine/Peach Pickers (days)



### Body Weight (kg, males)

Normal Distribution  
mean 76.90  
stand. dev. 11.88  
range: 50.00 to 105.00

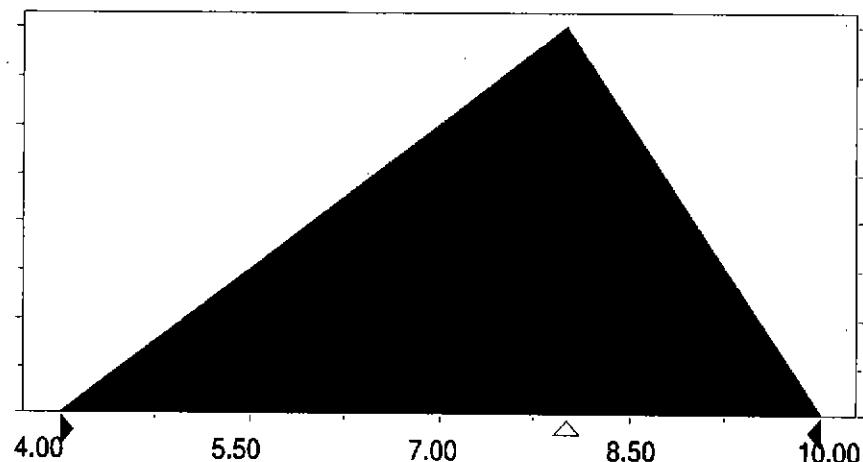
(WH&S, 1993)



### Hours Worked (per day)

Triangular Distribution  
minimum 4.0  
likeliest 8.0  
maximum 10.0

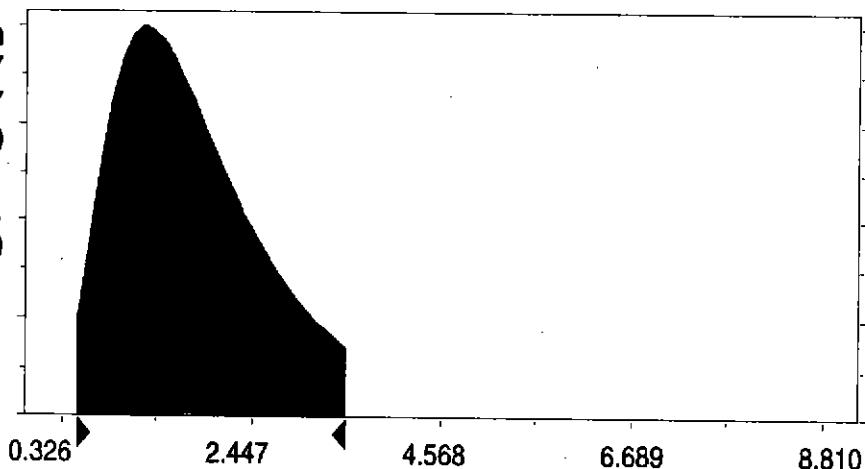
*(based on general observation by WH&S's field teams)*



### Initial Deposition ( $\mu\text{g}/\text{cm}^2$ )

Lognormal Distribution  
mean 1.97  
stand. dev. 1.17  
range: 0.50 to 3.50

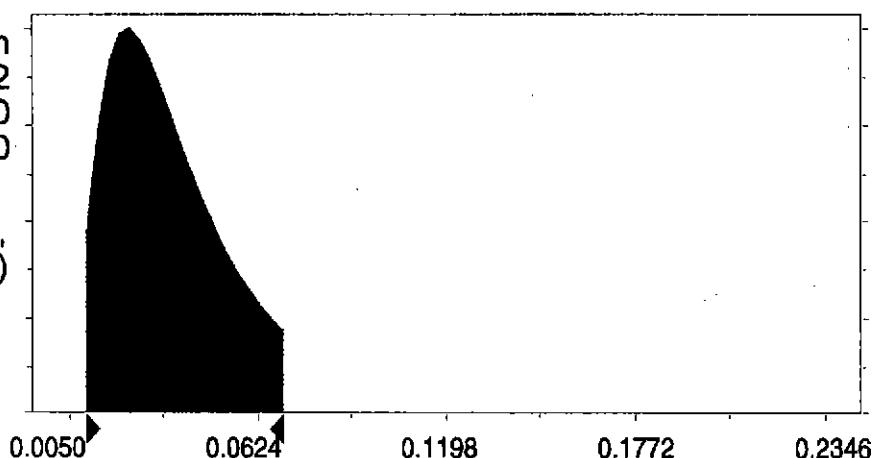
(Sanborn, 1989a, 1989b; Smith, 1991)



### Dissipation Rate ( $\mu\text{g}/\text{cm}^2$ per day)

Lognormal Distribution  
mean (-) 0.042  
stand. dev. 0.030  
range: 0.010 to 0.070

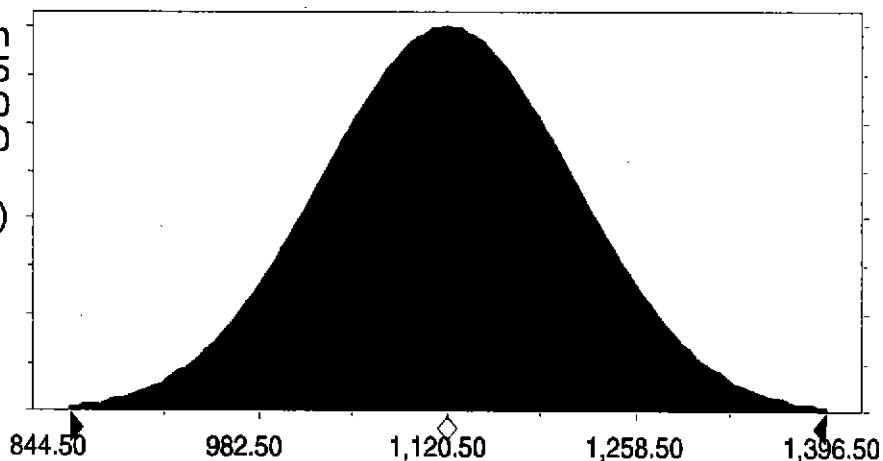
(Sanborn, 1989a,  
1989b; Smith, 1991)



### Transfer Factor (dermal)

Normal Distribution  
mean 1,120.5  
stand. dev. 92.0  
range: 800.0 to 1,450.0

(Rech, 1989)



**Table 1. Summary of Reentry Time from the Three Simulation Case Studies**

Work Group	Simulation (%ile, day) <sup>a</sup>			Point Estimate (day) <sup>b</sup>
	50th	75th	95th	
Greenhouse harvesters	0.02	0.03	2.22	4.70
Cotton Scouts	0.01	0.17	1.03	2.74
Nectarine/Peach Pickers	10.2	22.5	50.1	128
				15.8

<sup>a</sup> percentiles averaged over 10 simulation trials of 10,000 iterations each; simulation trials were implemented with the computer software *Crystal Ball* (1993).

<sup>b</sup> means were used mostly in the typical case whereas some high-end values were included in the extreme case.

## CONCLUSIONS

1. For most reentry day estimates we do not have the luxury of distributions for initial deposition/slope, TF, and dermal absorption, thus forcing the use of point estimates (typically with some extreme values).
2. Use of probabilistic distributions of data apparently makes predictions statistically more defensible.
3. Day of reentry estimation is most sensitive to initial deposition followed by dermal absorption and then hours worked in the 3 examples.
4. Use of just a few extreme case input variables (e.g., low body weight, high initial deposition) can significantly overpredict the 95th percentile of reentry day.
5. Better statistics do not necessarily mean more accurate predictions: some key input variables have large uncertainty, e.g., animal dermal absorption as surrogate for human.
6. Use of typical case point estimates currently practiced at the Department approximates 70th - 85th percentile of stochastic estimate.
7. Typical case point estimate is probably adequate for most decisions because a few input variables are *very* conservative (such as with use of animal dermal absorption as surrogate for human).

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